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# VIRTUAL LABORATORY/MODEL ABSTRACTION TESTBED

PAR Government Systems Corporation

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This scientific and technical report summarizes the work accomplished and information gained during the performance of AFRL/IFSB contract # F30602-98-C-0261, entitled Virtual Laboratory/Model Abstraction Testbed. The objective of this effort was to develop the foundation for a simulation model abstraction service, operating within the context of a distributed virtual laboratory within AFRL. Such a model abstraction service would create simpler versions of detailed simulation models that are compatible with the DoD High Level Architecture (HLA), consuming fewer resources while providing equivalent results. The vast majority of the work was performed on-site, and resulted in the establishment of an AFRL/IFSB modeling and simulation laboratory that will be used to support future model development, model abstraction, and analysis activities.

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# 1. INTRODUCTION

This scientific and technical report summarizes the work accomplished and information gained during the performance of AFRL/IFSB contract #F30602-98-C-0261, entitled Virtual Laboratory/Model Abstraction Testbed. The objective of this effort was to develop the foundation for a simulation model abstraction service, operating within the context of a distributed virtual laboratory within AFRL. Such a model abstraction service would create simpler versions of detailed simulation models that are compatible with the DoD High Level Architecture (HLA), consuming fewer resources while providing equivalent results. The vast majority of the work was performed on-site, and resulted in the establishment of an AFRL/IFSB modeling and simulation laboratory that will be used to support future model development, model abstraction, and analysis activities.

# 2. ACCOMPLISHMENTS

This effort was organized into two areas. The first involved the development of model abstraction concepts and capabilities, with the intent to create a model abstraction service. The second involved the development of a general-purpose distributed modeling and simulation capability to support the concept of a Virtual Laboratory. Originally, these two thrusts were considered to be of approximately equal priority. However, in practice, infrastructure development activities ended up taking precedence over the development of a model abstraction capability.

## *2.1 Model Abstraction*

The activities performed under this task included:

- Review of available literature on model abstraction and multi-resolution modeling,
- Identification of existing modeling and simulation programs and models for use in potential model abstraction experiments and demonstrations, and
- Development of a strategy for development of an IFSB model abstraction service.

Each of these activities is summarized below.

### 2.1.1 Model Abstraction Literature Review

Papers and reports describing various types of model abstraction techniques, including variable resolution modeling, combined modeling, multimodeling, and metamodeling were reviewed with the objective of deriving an architecture for a "toolbox" of model abstraction techniques. Several papers which organize model abstraction techniques into classification hierarchies were also examined. The hierarchy proposed by Coughlin and Sisti in "A Summary of Model Abstraction Techniques" was selected as the most appropriate to form the basis of a model abstraction toolbox. This hierarchy was selected because it focuses on the model abstraction processes, rather on the characteristics of the resulting models. This hierarchy differentiates model abstraction techniques first on the basis of whether they are primarily concerned with modifying the way that behavior is specified, or with modifying the structure of the model and/or its associated data.

### 2.1.2 Existing Modeling and Simulation Programs

Existing modeling and simulation programs were reviewed to identify those with potential relevance to AFRL/IFSB's mission and objectives. Programs examined included:

- AWSIM – the Air Warfare Simulation, a theater level simulation of air operations, used in the GAVTB demonstration,
- JSIMS – the Joint Simulation System, which is intended to support joint theater-level training,
- JWARS – the Joint Warfare Simulation System, which is intended to support joint theater-level analysis, and
- JMASS – the Joint Modeling and Simulation System, which is intended to support engineering-level models and simulation-based acquisition,

AWSIM is the current simulation used by the Air Force for theater-level modeling. It supports the Aggregation Level Simulation Protocol (ALSP), which allows it to communicate with other high-level simulations. AWSIM is currently being modified to work in conjunction with the Theater Battle Management Core Systems (TBMCS). Although AWSIM is still being supported by ESC, it will be replaced by the National Air and Space Model (NASM). NASM is the air and space component of the JSIMS system. Thus, while it makes sense for AFRL/IFSB to attempt to exploit AWSIM in the near term, any large investments of resources in it should be avoided.

JSIMS is being developed to be the new joint theater-level training system. It is being developed using a spiral approach, and is still in very early stages of development. JSIMS is being supported by a consortium of Government sponsors, each of which is developing models for their domain of interest. For example, the Air Force is developing NASM, which addresses air and space vehicles, sensors, and communications, while the Army is developing WARSIM 2000, which addresses ground forces. Common supporting services are being developed in a cooperative manner. The object models included in JSIMS will be of interest to AFRL/IFSB, but the training orientation of the system will cause it to be of, at best, limited relevance to IFSB's mission and objectives.

JWARS, as the new joint theater-level simulation-based analysis system, is far more relevant to AFRL/IFSB. The JWARS system is far simpler than the JSIMS system, and the software more readily available. Also, JWARS, since it is a theater-level analysis model, is an appropriate target for the products of a model abstraction process.

JMASS is an engineering-level model development system and simulation framework. Although it has recently become more associated with simulation-based design (SBD) and simulation-based acquisition (SBA), it is also appropriate for supporting detailed analyses of issues in the C4ISR domain. AFRL/IFSB can make significant contributions to the repository of JMASS models. Also, JMASS models should be the primary source for model abstraction processes.

### 2.1.3 Model Abstraction Service Strategy

Based on the results of the model abstraction literature review, and the examination of existing DoD modeling and simulation programs, a basic strategy for the development of a model abstraction service was developed. Such a service could be operated by AFRL/IFSB for the benefit of other DoD components, but could also be a key part of the AFRL/IFSB modeling and simulation infrastructure. The elements of this strategy include:

- JMASS, which is intended to support the development of detailed engineering-level models, should be the starting point for the construction of a model abstraction toolkit. Detailed JMASS models would be processed using a variety of techniques to create simpler models capable of producing equivalent results with fewer computational resources.
- JWARS should be a primary consumer of the products of a model abstraction service. Because of its theater-level scope, JWARS needs simple models that can be run much faster than real time, but which can still produce accurate results. JSIMS is also a potential major consumer of the products of a model abstraction service.

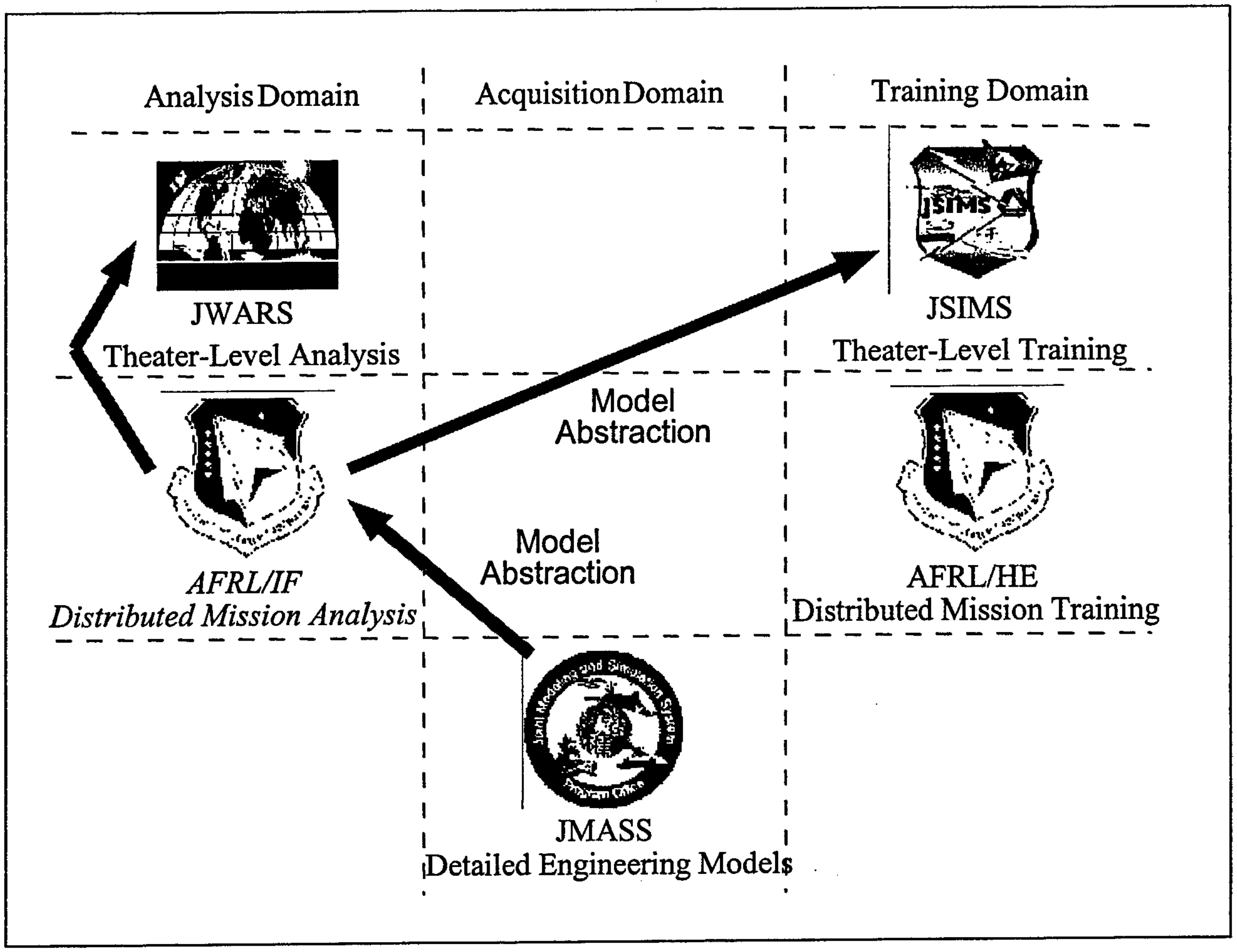


**Figure 1, Model Abstraction Service Strategy**

- Between the detailed JMASS models, and the abstract JWARS and JSIMS models, there is an intermediate level of analysis models which is not currently being addressed within the Air Force or DoD: Mission-level analysis, which would require models that are more abstract than those used with JMASS, but more detailed than those used by JWARS or JSIMS. A model abstraction service could be used to create such models, while elements of the JMASS and JWARS environments could be adapted to create a distributed, mission-level analysis capability.

Figure 1 shows the relationships among several current DoD modeling and simulation programs, and illustrates the model abstraction service strategy. The three columns in the table represent the three primary domains where modeling and simulation are used within DoD: analysis, acquisition, and training. The three rows represent different levels of abstraction (as well as scope); with theater-level simulations in the top row, mission level models and simulations in the middle row, and detailed models and simulations in the bottom row. The arrows show how detailed JMASS models could be abstracted for use in a mission-level analysis capability that AFRL/IFSB could develop, and how these mission-level models could then be further abstracted for use in JWARS and JSIMS.

### *2.2 Infrastructure Development*

A variety of activities were performed under this task, including:

- Supporting preparations for the Global Awareness Virtual Testbed (GAVTB) demonstration, including the acquisition and installation of two 9GB RAID drives for the IFSB modeling and simulation laboratory.
- Evaluation of the effectiveness of the GAVTB demonstration and the recommendation of improvements to make it more effective.
- Establishment of a temporary IFSB modeling and simulation laboratory in Room 1053 of Building 3.
- Attempting to reconstitute the GAVTB demonstration (AWSIM & GIAC) in the temporary IFSB modeling and simulation laboratory, including the use of multicast tunneling techniques in conjunction with the DIS protocol,
- Installation, testing, and debugging of the ShareWeb software developed by the Institute for Simulation and Training (IST),
- Installation and use of new versions of the IVIEW 2000 software developed by Amherst Systems to simultaneously display DIS PDUs from multiple CGF programs,
- Installation and debugging of TERSM software,
- Evaluation and experimentation with the government off-the-shelf (GOTS) High Level Architecture (HLA) tools developed under the sponsorship of the Defense Modeling and Simulation Office (DMSO), using them to create a simple Federation Object Model (FOM),
- Experimentation with DMSO's HLA Run-Time Infrastructure (RTI ) Version 1.3 software for the Sun and SGI platforms,
- Supporting the planning and establishment of IFSB modeling and simulation laboratory facilities within the C2 Technology Laboratory, including workstations, PCs, printers, networking, and the Smart Board,
- Developing Data Wall window labeling and arrangement utilities to enhance future GAVTB and other demonstrations,
- Experimenting with several software packages and technologies, including DII COE, JMTK, Java, and JDBC, to enhance future GAVTB demonstrations.

Each of these activities is summarized below.

### 2.2.1 GAVTB Demonstration Preparation

The Global Awareness Virtual Testbed demonstration was held on 23 September 1998, in the $C^2$ Technology Laboratory (C2TL) at AFRL Rome Research Site. This demonstration was the culmination of an SBIR effort performed by Frontier Technologies. The objective of the demonstration was to show how the analysis of relevant command and control issues could be assimilated in a distributed, collaborative manner. The demonstration involved a scenario generated using the Air Warfare Simulator (AWSIM), running in the C2TL. Friendly UAVs were simulated using a Frontier Technologies model named AFTREM, which was run in Frontier's office in Washington, DC. Possible enemy TEL detections generated by AFTREM were processed by analysis software running at AFRL in Dayton, Ohio. Confirmed TEL detections were sent back to AFRL in Rome, where they were processed and displayed on a map background on the Data Wall in the C2TL. This information was then used by the demonstration "commander" to assign current combat air patrol missions to intercept, attack, and destroy the TELs. Analysis metrics included the number of missions flown and the number of TELs destroyed, as a function of the delay times for reported detections.

PAR assisted IFSB staff in planning and preparation for the GAVTB demonstration, including the definition of hardware, system software, and networking requirements and the identification of candidate configurations. At the request of IFSB, PAR acquired, delivered, and installed two 9GB removable RAID drives which were needed to support the GAVTB demonstration.

### 2.2.2 GAVTB Demonstration Evaluation

Following the GAVTB demonstration, PAR performed an evaluation of its effectiveness, and produced a set of detailed recommendations for enhancing the demonstration. These recommendations addressed the presentation of the demonstration, the demonstration displays, the simulation models, the demonstration scenario, and the analysis performed. Some of these recommendations provided the basis for the development of some Data Wall display support utilities, while the remainder formed the foundation for the current Model Interoperability for Global Awareness (MIGA) effort.

### 2.2.3 Temporary IFSB Modeling and Simulation Laboratory Facility

Also following the GAVTB demonstration, PAR assisted IFSB staff in establishing a temporary modeling and simulation laboratory facility in Room 1053 of Building 3. This facility, which included networked Sun, SGI, and PC workstations, was used to support IFSB activities for several months, until the furnishings and equipment for the permanent IFSB modeling and simulation laboratory in the C2TL arrived.

### 2.2.4 GAVTB Demonstration Reconstitution

Following the GAVTB demonstration, PAR assisted IFSB staff in attempting to reconstitute the GAVTB demonstration software in the temporary modeling and simulation laboratory facility. This was necessary since the hardware, system software, and networking configuration used to support the GAVTB demonstration was a one-time arrangement, involving a number of resources not controlled by IFSB. Unfortunately, the GAVTB demonstration software left behind by Frontier Technologies could not be successfully transferred to the modeling and simulation laboratory hardware. Also, the documentation provided was completely inadequate with respect to allowing the software to be reinstalled and/or rebuilt on a different hardware configuration. To date, all attempts to reconstitute the GAVTB demonstration have been unsuccessful. Under the MIGA contract, efforts to obtain and install a new version of the AWSIM software are continuing.

### 2.2.5 ShareWeb Installation, Testing, and Debugging

ShareWeb is a World Wide Web-based distributed simulation package developed by the Institute for Simulation and Training (IST) for AFRL/IFSB. This software was developed to study the effects of network latency over a Wide Area Network (WAN) as it pertains to web-based collaborative environments. PAR assisted in the installation of the ShareWeb software in the IFSB modeling and simulation laboratory. PAR also worked in collaboration over the Internet with the developers at IST in Orlando, Florida to support the testing, and debugging of the ShareWeb software and was also involved in the network latency data collection.

### 2.2.6 IVIEW 2000 Installation and Use

IVIEW 2000 is a visualization tool developed by Amherst Systems that allows the dynamic 3D flight paths of aircraft and missiles to be displayed. PAR assisted in the installation of an updated version of the IVIEW 2000 software in the IFSB modeling and simulation laboratory facility. PAR later used the IVIEW 2000 software to simultaneously display Distributed Interactive Simulation (DIS) Protocol Data Units (PDUs) from multiple Computer Generated Forces (CGF) programs. IVIEW 2000 was later modified by PAR to meet the requirements of Solaris 2.6 and IRIX 6.4 and 6.5.

### 2.2.7 TERSM Installation and Debugging

PAR installed the Tactical Electronic Reconnaissance Simulation Model (TERSM) software in the IFSB modeling and simulation laboratory, and assisted in its debugging. This software will be used as a baseline model for electronic sensor detection and will then be compared and contrasted to other IFSB detection models that use neural network and Hebbian Learning algorithmic methods.

### 2.2.8 HLA Tool Evaluation

PAR obtained, installed, and experimented with several government off-the-shelf (GOTS) software tools that support the High Level Architecture (HLA), in the IFSB modeling and simulation laboratory facility. These tools were developed under the sponsorship of the Defense Modeling and Simulation Office (DMSO). The tools support the specification of Simulation Object Models (SOMs) and Federation Object Models (FOMs). They were used to create a simple example of a Federation Object Model (FOM).

### 2.2.9 RTI Experimentation

PAR also obtained, installed, and experimented with DMSO's HLA Run-Time Infrastructure (RTI ) Version 1.3 software for the Sun and SGI platforms. Experiments were conducted to test the distributed architecture of this software over both a local area and wide area network. A multicast router was set up between two subnets to facilitate the forwarding of simulation information over non-multicast enabled routers.

### 2.2.10 IFSB Modeling and Simulation Laboratory Facility

PAR assisted IFSB staff in the planning and establishment of the permanent IFSB modeling and simulation laboratory facility within the C2TL. This included the installation of hardware and system software; including workstations, network appliances, CDROM servers, PCs, printers, switches, projectors, and the Smart Board.

PAR currently assists in maintaining this development environment, working in conjunction with IFSB staff in the functional areas of software and hardware upgrades as well as system security tasks.

### 2.2.11 Data Wall Utilities

It was observed during the evaluation of the GAVTB demonstration that the audience had difficulty keeping track of which information was being conveyed by each window on the Data Wall. For example, display windows showing Ground Truth, Intelligence, and Operations displays all had similar map backgrounds, and similar symbology, but different content. It was recommended that utility software be developed that would allow each Data Wall window to have a large, easily readable label just above it. Whenever a display window was moved or resized, its label would be moved or resized along with it. Working with IFSB staff, PAR subsequently developed such a Data Wall window labeling utility, which will be used to enhance future GAVTB demonstrations, and any other demonstrations that involve the display of multiple windows on the Data Wall.

### 2.2.12 DII COE and JMTK Experimentation

In an effort to find a standard map background display capability for the IFSB modeling and simulation laboratory, PAR experimented with the Defense Information Infrastructure (DII) Common Operating Environment (COE). This environment, which is a customized version of the Solaris Common Desktop Environment (CDE), includes standard applications, utilities, and toolkits. One of its components is the Joint Mapping Tool Kit (JMTK), which is being developed by the National Imagery and Mapping Agency (NIMA) and the Defense Information Systems Agency (DISA). It includes a utilities segment (JMU), a spatial database management segment (JMS), a terrain analysis segment (JMA), and a visualization segment (JMV). The NIMA Map Viewer (NMV) is an application that has been developed on top of JMTK to display various types of NIMA standard raster, gridded, and vector digital map products. PAR attempted to install and use DII COE, JMTK, and NMV for use as a standard map display. Unfortunately, a number of difficulties were encountered, primarily due to the fact that JMS, JMV, and NMV were created by different contractors, but are interdependent, and are all continuing to evolve, with new releases every six months. Further work with JMTK and NMV, using newer releases, is planned.

### 2.2.13 JAVA and JDBC Experimentation

PAR also experimented with Java to create data visualization tools that can be used to enhance future GAVTB demonstrations, as well as other IFSB modeling and simulation demonstrations. Working in conjunction with IFSB staff, a Java-based 3D visualization tool, JVIEW, was developed in the IFSB modeling and simulation laboratory. This tool works in conjunction with the Data Wall to display various types of dynamic, three-dimensional information, such as battle space energies, terrain models, and simulation entity viewing.

JDBC was experimented with to evaluate its capabilities for use in a joint IFSA/IFSB project. JDBC is the Java database connectivity application programming interface (API) available in the Java 2 Platform software.

# 3. CONCLUSIONS and RECOMMENDATIONS

This effort successfully performed a number of activities that helped to build the foundations for a virtual, distributed C4ISR modeling and simulation laboratory facility. However, a great deal remains to be done to fully meet the objectives associated with AFRL/IFSB's mission. Since it was not possible to successfully reconstitute the GAVTB demonstration in the IFSB modeling and simulation laboratory, additional effort needs to be tightly focused on achieving an improved simulation-based analysis capability that can address critical C4ISR issues.

It is recommended that AFRL/IFSB continue to work with the AWSIM simulation for the time being, using it as the basis for developing an enhanced GAVTB demonstration. A version of AWSIM is being developed which will interface with the TBMCS Air Operations Data Base (AODB). This version should be used to construct one or more demonstrations in which TBMCS is used to monitor the execution of simulated missions, and in which missions can be modified by entering new orders into AWSIM. The development of NASM should continue to be monitored, as it will eventually replace AWSIM. JMTK, and the NIMA Map Viewer, should continue to be monitored as a possible source for a standard map background display capability. Improvements to Data Wall support software that will enhance the control and presentation of distributed modeling and simulation demonstrations, such as support for label windows, should continue to be developed.

Ideally, this capability would be distributed across multiple physical locations, including AFRL/IF facilities in Dayton as well as in Rome. However, two factors greatly complicate the achievement of such a capability. First, the necessary networking services for all of the distributed locations must be provided as AFRL infrastructure. It is essentially impossible for any one branch, or even several branches in collaboration, to achieve the necessary capabilities. This obstacle is further complicated by the possible use of classified data sources in the simulation. Although the use of classified data may make the results of the simulation much more realistic, it requires classified network support for all of the necessary networking services to be available. This normally involves a completely different networking infrastructure than is used at the unclassified level.

Therefore, it is recommended that the development of initial capabilities avoid both wide area networking and the use of classified data. The availability of both unclassified and classified networking capabilities connecting physically distributed elements of AFRL should be pursued as a separate strategy.

It is recommended that AFRL/IFSB obtain the JMASS 98 software and models and become an active member of the JMASS community of model developers and users. The JMASS model development infrastructure will provide a framework for the development of a model abstraction service, incorporating multiple techniques. This will also provide access to a number of existing models that can be exploited. AFRL/IFSB can play a significant role in expanding the collection of JMASS models.

It is recommended that AFRL/IFSB also obtain the JWARS software and become part of the JWARS user community. JWARS should become the primary consumer of the simplified analysis models that would be products of a model abstraction service. Comparison of the object model frameworks of JMASS and JWARS should be extremely instructive.

As a long term objective, AFRL/IFSB should consider defining an intermediate, mission-level analysis capability. This capability could form the objective around which a collaborative AFRL/IF HLA federation could be developed, with various AFRL/IF divisions and branches contributing individual models. The models used at this level would be less detailed than the engineering models used by JMASS, but more detailed than the theater-level JWARS models. This level of analysis does not currently appear to be being addressed within the Air Force, or within DoD in general. The models needed by this capability would be created by applying model abstraction techniques to JMASS models and other existing detailed models.